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THE NEBULAR LINE 3869 IN R AQUARII

After the discovery by Dr. P. W. Merrill of the presence of the bright nebular lines 5015, 4957 and 4363 A in the spectrum of the variable star R *Aquarii*, a spectrogram of this object was secured at Mount Hamilton, on November 3, 1919, with a one-prism spectrograph (linear dispersion at $H\gamma$ 1 mm. = 57 A) and the 36-inch refractor. The spectrogram, obtained with an exposure of three and a half hours, is of good density from 3868 to 5167 A. It shows, in addition to the nebular and hydrogen lines described in Dr. Merrill's paper in this number of the PUBLICATIONS, the bright nebular line, whose wave-length as determined by Wright,[1] from measures in the spectra of the gaseous nebulae, is 3868.9 A (Rowland).

Mount Hamilton, J. H. MOORE.
November 10, 1919.

COMMENTS ON THE OCCURRENCE OF NEBULAR LINES IN THE SPECTRUM OF R AQUARII

The discovery by Dr. Merrill of three of the brighter nebular lines in the spectrum of R *Aquarii*, an otherwise typical star of Class Md, is of the highest interest. It appears to be the first recorded instance of the association of peculiarly nebular lines with the spectrum of a red star, and is possibly of significance as establishing contact between these two classes of objects. The occurrence of the bright lines of hydrogen, and possibly of helium, in their spectra, has long been recognized as an outstanding peculiarity of the red variables, but the characteristically nebular lines have, until now, been looked for in vain. On the other hand there is abundant evidence connecting the gaseous nebulae with the white or "hot" stars, particularly with that extreme group, the Class O, or Wolf-Rayet stars. Since these, on the one hand, and the red variables, on the other, appear to have nothing else in common, it is going to be somewhat disconcerting if both groups are found to be related to the gaseous nebulae.

As the matter stands, there can be no question as to the presence of the four nebular lines: N_1, N_2, 4363, and 3869 A (the last of these having been observed by Dr. Moore, as stated elsewhere in this issue) in the spectrum of R *Aquarii*. Dr. Merrill's observations of the shortness of the nebular lines is confirmed by plates secured with the slitless spectrograph attached to the Crossley telescope of this observatory; in particular the N_1 image, which is the most suitable for observation, records, on these plates, as a point. Quite aside from this Dr. Merrill has brought out other arguments, which of themselves constitute ample proof that the nebular lines belong to the stellar spectrum. That much must be admitted. But there are certain differences in the habit of hydrogen in the Md stars, in the one case, and in those of Class O in the other, to which it seems worth while at this juncture to draw attention. In a Class O star the hydrogen is outstanding. When such an object is surrounded by a visible nebula the bright hydrogen lines reach out into it. In the Md stars, on the other hand, the glowing hydrogen is undoubtedly deep down in the star. Pickering's explanation of the absence (or weakness) of the $H\epsilon$ line of hydrogen, on the assumption that it is absorbed by the broad H calcium band, not only accounts satisfactorily for the missing hydrogen member, but shows, as well, that hydrogen radiation is emitted below the surface of the calcium absorbing layer, and while Pickering's hypothesis has been somewhat doubtfully accepted by certain astronomers for the very reason that it predicates an inversion of this character, it is altogether probable that it is correct, and furthermore, that the great irregularity which he reported in the intensities of some of the other lines in the series is also due to absorption in the atmosphere of the star; in particular, the weakness of $H\beta$ in *o Ceti* probably results from the fact that it lies within one of the lesser of titanium oxide bands which Professor Fowler has shown to be the cause of the dark flutings in Class M spectra.

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[1] *Pub. Lick. Obs.*, **13**, 242, 1919.

There is little question then that in the Class Md stars the glowing hydrogen lies at a very considerable depth in the stellar atmosphere; is the same true with respect to "nebulium"—using that much abused term in the widest and most general sense to cover the origin of all of the "unknown" nebular lines? It seems likely that it is. Among the many lines in the gaseous nebulae there are certain pairs or groups which appear to belong together. N_1 and N_2 form such a pair, and 3869 and 3967 A may be said, with almost an equal degree of certainty, to compose another. The former of these two lines is quite the brighter, but, as photographed with the single prism spectrograph attached to the 36-inch refractor, the intensity of the two is about equalized by the excess of absorption by the glass on the line of shorter wave-length, so that when photographed with that apparatus the two lines appear to be very nearly of the same strength, 3869 remaining a little the brighter, unless, as is the case in small objects, it is weakened by the chromatic aberration of the telescope. One of the lines is close to a hydrogen line, which interferes in some instances with the observation, but, as nearly as I have been able to determine, the intensity ratio of the two is practically constant in 37 out of the 40 nebulae that I have observed; in the remaining 3 neither of the lines in question is present. Furthermore the two lines have the same behavior in respect to distribution in those nebulae that are not homogeneous. They occurred together in the spectrum of Nova Persei No. 2. I think they are undoubtedly to be regarded as linked.[1]

Dr. Moore has photographed one of these lines (3869 A) in R *Aquarii*, but the other is not there, or at least, if it is, it is so feeble as to be indistinguishable in the dark line spectrum. Photographs with the slitless spectrograph confirm this observation. I cannot but regard it as significant that the position of the missing line lies very close to that of H calcium and falls within the spread of the calcium line in the spectrum of R *Aquarii.* It lies closer in fact to H than does Hε, the wave-lengths of the three lines being as follows:

	I. A.	
Nebular line.............	3967.51	
		−.97[*]
H calcium...............	3968.48	
		+1.74[*]
Hε hydrogen.............	3970.22	

Other things being equal, the conditions for absorption are therefore at least as good for the nebular line as for Hε. I cannot but regard it as probable that the absence, or weakness, of 3967 A is like that of Hε due to calcium absorption, and, if this construction be accepted, the origin of the line must, like that of Hε, be placed well within the calcium atmosphere.

With respect to N_1 and N_2 the conclusions are not so certain. Both of these lines lie within one of the strongest titanium oxide absorption bands in the spectrum, N_2 falling in the dense and nearly opaque head of the band. The fact that any light whatever gets thru at N_2 suggests that this line is not subject to the full absorptive effect of the titanium oxide atmosphere.[2] N_1 lies in a somewhat lighter part of the band, but is within a lesser and overlapping dark fluting, so the conditions for transparency are here a little, tho not very much, better than at N_2. Under the conditions any considerable submergence of nebulium, with respect to titanium oxide vapor, would result in a slight excess in the intensity of N_1 relatively to N_2. A number of experiments have been undertaken for the purpose of finding out whether such an effect exists. In one of them the spectrum of a gaseous nebula (N. G. C. 7027) was photographed over that of *α Herculis*, a class Mb star, which shows, of course, the titanium oxide flutings. One receives the impression that, with respect to N_2, the chief nebular line N_1 is somewhat stronger in the spectrum of R *Aquarii* than it is in this "synthetic" spectrum, but since the density function of a photographic plate varies with the wave-length, particularly in the blue-green, the matter can be settled definitely only on the basis of equal exposure intervals for star and nebula, which it has not yet been found practicable to make. Speaking generally, on the basis of the incomplete evidence at present available, it seems probable that the nebulium radiation is slightly affected by titanium oxide absorption, but is not subject to the full measure of extinction which that vapor exercises on the light of the star. If we assume that the pair 3869—3967A is emitted at the same level as N_1 and N_2 the level of nebulium, and probably of titanium oxide, is found to be below a very considerable portion of the star's calcium atmosphere. However, the last assumption is, perhaps, not justifiable; in the nebulae different groups of lines frequently have vastly different distributions, and the premise of equal levels of the origins of the two pairs may, perhaps, not reasonably be made.

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[1] See forthcoming *Pub. Lick Obs.*, **13**, part VI, chap. IV.

[*] In *o Ceti* and *χ Cygni*, typical Md stars, the bright hydrogen lines are displaced about −0.3 A with respect to the dark line system. If we assume this displacement to be normal for stars of their class the tabular residuals should be corrected by that amount, but even so the nebular line would remain the closer of the two.

The foregoing considerations are, of course, highly speculative, and are based on a number of assumptions, one, perhaps the most serious, of which has not been explicitly stated, namely, that an object like R *Aquarii* is a single and fairly homogeneous star. To what extent this and the other assumptions conform with the facts, we have at present no means of judging; still with all the uncertainty it seems worth while to draw attention to these apparent peculiarities in the behavior of particular lines in the spectra of the Md stars, not only because they indicate a difference in the conditions under which bright line radiation takes place in these stars on the one hand, and in some of the white stars and the nebulae, on the other, but also because they may prove suggestive in the study of the nature of the red variables. The observers of the Harvard College Observatory have noted numerous irregularities in the intensities of the members of the hydrogen series of bright lines, which undoubtedly will repay close study.

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[2] The assumption is here made that, under identical conditions, the nebular bright lines would be subject to the same absorption by the titanium oxide as that which the latter exerts on the continuous spectrum. The bright lines are probably sufficiently broad, and the lines of the flutings close enough together, to insure this being the case.

I wish to acknowledge my indebtedness to Dr. Merrill for the use of a print of the spectrum of R *Aquarii* and to Dr. Moore for the privilege of examining the plate secured by him.

November, 1919. W. H. WRIGHT.

SPECTROSCOPIC OBSERVATIONS OF TWO RECENTLY DISCOVERED NOVAE

The two new stars recently announced by Professor Bailey of the Harvard College Observatory as having been discovered there by Miss Mackie have been examined spectroscopically at the Lick Observatory.

Nova Sagittae, R.A. = $20^h 3^m.1$; Dec. = $+17^\circ.6$ (1900) *H.C.O. Circular* No. 219. This star is reported to have appeared as a nova of 7.2 magnitude in 1913. It is now relatively faint and is described as closely following a 14.5 magnitude star. Preliminary to a spectroscopic observation of its spectrum a finding plate was kindly photographed by Dr. Curtis with the Crossley reflecting telescope. On this plate the nova is much brighter than the companion referred to above.

Two spectrograms have been secured with the small slitless spectrograph attached to the Crossley reflector. The dispersion is very low and the record faint but the general character of the spectrum is apparent. It is continuous and lies chiefly in the ultraviolet. The intensity is pretty uniform thruout its length. While no bright nor dark bands are visible in the spectrum the possibility of their existence is not precluded; the dispersion used is very weak and the observation can be taken as establishing only the general nature of the radiation.

The stellar image on Dr. Curtis's plates is stronger than one would be led to expect from the Harvard description of it; it is particularly intense on a Seed No. 23 plate, as compared with a No. 30. This is doubtless to be accounted for by the spectral peculiarity of the star. Its light lies very largely in a region to